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Spectral analysis the information signal in the identification of the recurrent laryngeal nerve in thyroid surgery

Abstract. *The task of identification the recurrent laryngeal nerve during thyroid surgery based on spectral analysis of the information signal is presented. A method based on the nerve reaction to the stimulation of the surgical wound by the alternated current was considered.*

Streszczenie. *Celem autorów jest opracowanie metody identyfikacji położenia nerwu krtaniowego w czasie operacji tarczycy. Rozpatrzono metodę opartą o stymulację pola operacji przez prąd przemienny. (**Analiza widmowa sygnału w identyfikacji położenia nerwu krtaniowego podczas operacji tarczycy**)*

Keywords: Spectral Analysis, Information Signal, Thyroid Surgery, Laryngeal Nerve.
Słowa kluczowe: in the case of foreign Authors in this line the Editor inserts Polish translation of keywords.

Introduction

The principle of operation the modern technical devices for identification the recurrent laryngeal nerve (RLN) during thyroid surgery is based on the surgery area stimulation by alternating electric current and assessing the results of stimulation on the vocal cords [1]. If the area of stimulation includes RLN, then it takes place contraction the muscles stretching vocal cords, if the muscle tissue is stimulated, then the response is low. During the airflow passing through the larynx the vocal cords vibration creates sound vibrations, which are recorded by sound sensor. Information signal from the sound sensor is processed in a personal computer. In the existing method of RLN identification the informative parameter is the amplitude of information signal which extracted by filter with band width that within the limits of stimulating signal frequency [2]. The closer is point of stimulation in the surgical wound to RLN, the higher is information signal amplitude. The existing method of information signal processing has a significant shortcoming, such as low sensitivity. That is the signal amplitude is so high for direct stimulation the RLN and steeply reduced (to noise level) at a slight distance from it. This fact significantly reduces the possibility of visualization the RLN position and increases the risk of its damage during surgery.

The higher marked stipulated realization the further researches with goal of discover the other informative characteristics of information signal.

The basic idea of proposed approach

As is well known the spectrum is one of main characteristics of signal. Taking into account that the stimulation of tissues in surgical wound made by electric current with a given frequency, it was advanced the hypothesis that is possible the modulation (low frequencies signal) of noise-like signal by vocal cords vibration. This noise-like signal is caused by passing the airflow through the patient's larynx. The purpose of this investigation is to identify in the spectrum of the resulting information signal the spectral components of stimulation signal (modulating signal). The scheme described effect is shown in Fig. 1.

As shown in Fig. 1 the resulting information signal which spectrum is used for identification the RLN location, obtained from the nonlinear transformation of two signals. The first of these is the stimulation signal and the second is the signal generated by sound vibrations arising from the airflow passing through the patient's larynx. Unfortunately the nature of this non-linear transformation to date has not been sufficiently researched. The nature of processes the electrical impulses transmission through the nerves for control the muscle tissues described in [3]. In particular, the process of impulses transmission by RLN through synapse to the muscle tissue. However, the passing of alternating current, which in our case is a stimulation signal, and also the effect of its transmission through the synapse to contract the muscles that control the vocal cords remain unresearched. On the other hand the signal spectrum generated by the airflow passing through the patient's larynx essentially depends on the patient's physiology. Therefore, predicting the changes in the signal's spectrum due to contraction the muscles that control the vocal cords is a enough complicated task. Under these conditions the experimental research of proposed hypothesis is the only possible.

Results of experimental verification

For research the information signal spectrum as response to stimulation the device was designed [2]. Its functional scheme is next: stimulation the tissues in the surgical wound by alternating current of fixed frequency from alternator, for which provided the small electrical conductivity in muscle tissues in surgical wound and high electrical conductivity in RLN and muscles that control the vocal cords tension. Then the vocal cords contraction on the given frequency is registered by sound sensor installed in the respiratory tube which placed in patient's larynx. After that this signal is transformed to the electrical signal which is going for further processing (spectrum extraction) to personal computer. It is necessary to notice that as opposed to device in the existent method of identification the RLN placing [2] in this case a band filter for selection from information signal the constituent of stimulation signal is absent.

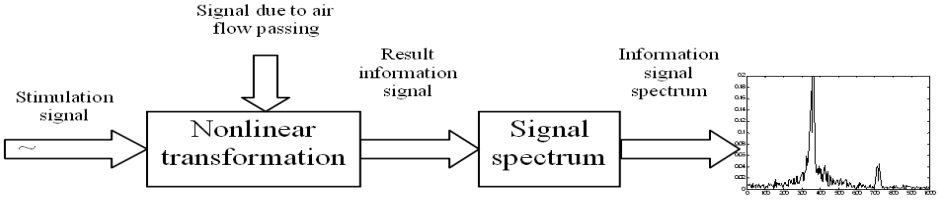


Fig. 1. Scheme of receiving the spectral components of stimulation signal

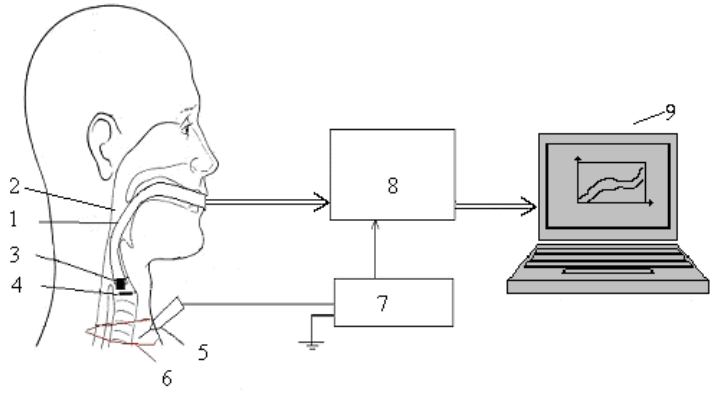


Fig. 2. Scheme of receiving the information signal for RLN identification

Initial information signal was got in the process of surgical operations on a thyroid for over 20 patients. The tissues stimulation in surgical wound was carried out by an alternating current on frequencies from 100 to 400 Hz. An extraction the spectrum of information signal is conducted in Matlab by FFT function.

In the process of research three groups of specific (for the certain group of patients) fragments of information signals and their corresponding spectrums were separated. There are shown on Fig. 3 these fragments got in case of stimulation current with frequency 320 Hz.

Fig. 3 a) show typical for the first group of patients the voice signal got as a result of airflow passing through respiratory tract, signal - reaction on the RLN stimulation (8 second), and also spectrum of this signal. From Fig. 3 a) also evidently, that in the spectrum of extracted signal there is not a spectral constituent of stimulation signal with frequency 320 Hz. Additional research showed that this situation was typical for the certain group of patients and explained by physiology properties of their larynx. The conducted research also gave explanation the reasons for low reliability of identification the RLN placing by the known method [2] for this group of patients, because a band filter within the limits of RLN stimulation signal's frequency fully kill an information signal – reaction on a stimulation.

Fig. 3 b) show typical for the second group of patients the voice signal – reaction on the RLN stimulation, got as a result of airflow passing through respiratory tract, and also its spectrum. From Fig. 3 b) also evidently, that in the spectrum of the extracted signal a spectral constituent with 320 Hz frequency of RLN stimulation dominate. Additional research showed that this situation was typical for the considerable group of patients that provided reliable identification of RLN placing by an existent method [2] for this group of patients.

At last Fig. 3 c) show typical for the third group of patients the voice signal got as a result of airflow passing through respiratory tract, signal – reaction on the RLN stimulation (4 second), and also spectrum of this signal. Typical spectrums for this group of patients show that their spectral constituents within the limit from 240 to 300 Hz dominate though the RLN was stimulated on frequency 320 Hz. Additional research showed that this situation was typical also for the considerable group of patients. Therefore the use of band filter with some wider pass band than for the second group of patients provided enough reliable identification of RLN placing by an existent method [2] for this group of patients.

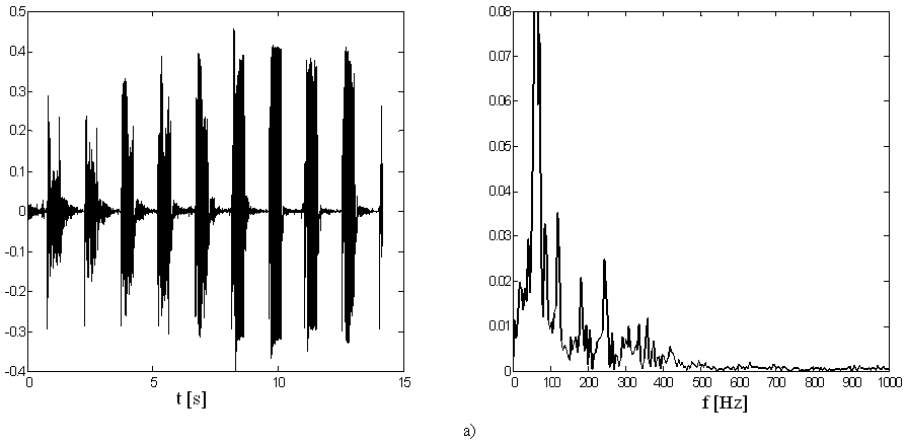
During the researches also it was investigated:

1) the lower frequency of alternating current for stimulation the RLN, the clearer it appears in the spectrum of the output information signal;

2) features of every patient larynx significantly affect the difficulty identifying the component of stimulation current frequency in the spectrum of the resulting information signal and in most cases impossible to identify this component by existing method [3];

3) if the point of stimulation at the surgical wound is near to RLN observed specific sound vibrations that can be identified by ear, which can serve as a reliable basis for identifying the distance to the RLN.

Under these conditions with the purpose increasing the reliability and accuracy of identification the placing of RLN in the process of surgical operation on a thyroid there is a need to create "intelligent" classifier the parameters of information signal – reaction on tissues stimulation in surgical wound.



a)

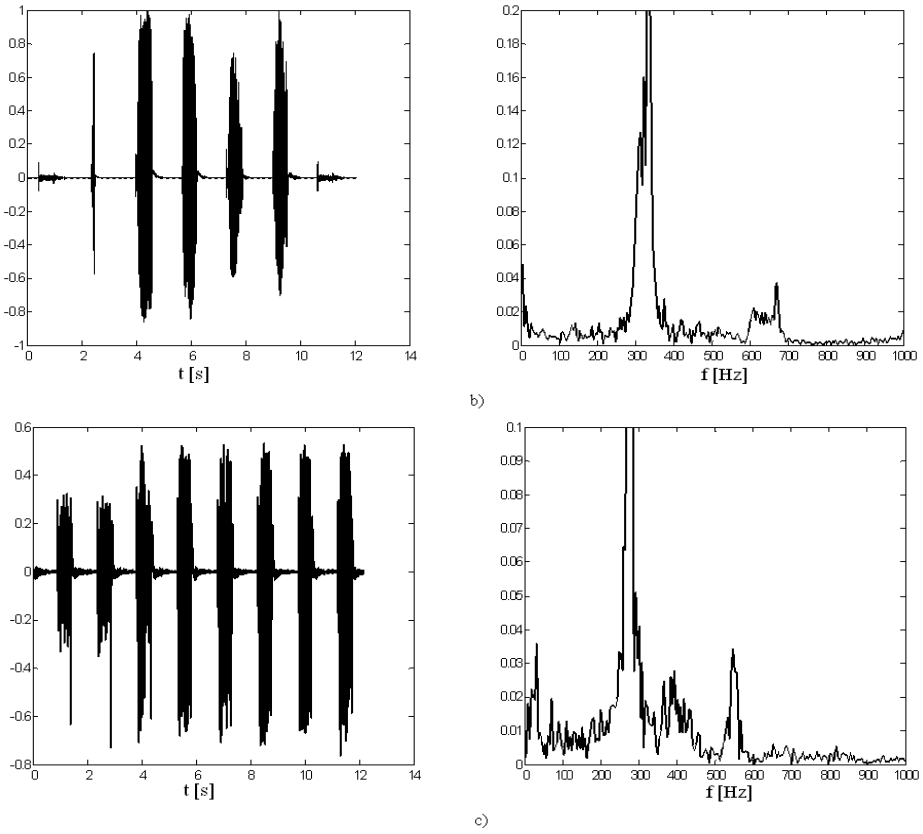


Fig. 3. Information signal fragments and their corresponding spectra

Conclusions

Based on the conducted research it is possible to conclude that a «noise» component for analysis the influence of spectrum the resulting information signal on quality of RLN identification and visualization in the process of surgical operation on a thyroid there are features of patients larynx. It is determined that specific voice vibrations that appear during tissue stimulation in surgical wound by an alternating current can serve as a reliable sign for identification the distance to RLN, that is why creation the "intelligent" classifier of information signal parameters – reaction on tissues stimulation in surgical wound is actual.

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